

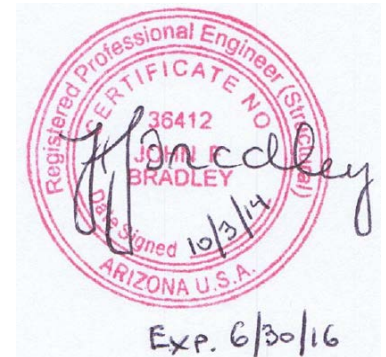
Rev	Date	Description	Prepared by: John F. Bradley, S.E. Arizona Registered Structural Engineer Lic. #36412 Atascadero, California	JOB NO. 2408160
0	10/3/14	Orig		SHT 1 OF 17
			FOR Hopper H1 (270 cu ft Capacity)	DATE 10/3/2014
			DESCRIPTION Design of Vessel & Supports	DES. BY JFB
				REV 0

STRUCTURAL CALCULATIONS FOR
Hopper H1 (270 cu ft Capacity)
Design of Vessel & Supports
Double Wall Stainless Steel
14.17 ft x 8.25 ft x 7 ft Tall Supported by Concrete Vault

REVISION 0

Dated October 03, 2014
 (Original Calc Package)

LOCATED AT
Parker, Arizona



Calculations Prepared For:
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For: Evoqua Water Technologies
Parker, Arizona
By: John F. Bradley, S.E.
October 3, 2014

Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
Sheet 2

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For: Evoqua Water Technologies
Parker, Arizona
By: John F. Bradley, S.E.
October 3, 2014

Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
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Design Summary

Product Stored: Spent Activated Carbon (Design for Both Liquid Slurry & Dry Granular Material)
Specific Gravity: 1.50
Max Temperature: 150° F
Design Pressure: Atmospheric
Design Codes: 1) API 650 11th Edition
2) IBC 2012 for Seismic
Wind Design: Vessel is indoors; wind is not considered
Seismic Design: IBC 2012: $S_s = 0.23g$, $S_1 = 0.15g$, $I_e = 1.5$, Site Class D

Description

This vessel is a double-wall inverted pyramid hopper for use inside a water treatment plant near Parker, Arizona. Product is spent activated carbon granular material (both liquid slurry and dry granular material). Material used for the tank construction is SS304 stainless steel except for the inner shell in contact with product which is SS316. Inner shell is separated from outer shell by (12) evenly spaced bent plate channel spacers @ 1 1/2" tall. These spacers are attached to inside of outer shell. Inner shell is 3/8" thick SS316 plate, and outer shell is 1/4" SS304 plate.

Design Criteria

Specific gravity of product is provided by customer at 1.50 (conservative). Tank is designed for atmospheric pressure (no internal pressure or vacuum) and ambient temperature. Design codes used for this tank are API 650 and IBC 2012. There are no American codes that specifically address all components of hoppers, so other codes & design procedures will be used as appropriate. Allowable steel stresses are taken per API 650. Wind and seismic loads are calculated both per IBC 2012, and load combinations are taken per IBC 2012. Seismic design values above are from USGS website for Parker, AZ.

Design Methodology

The Inner tank shell is the normal pressure boundary; the outer tank is used for leak containment. Under normal loading, inner shell transfers loads to the outer shell at discreet locations of spacers. In event of leak in inner shell, space between the two shells may fill up, subjecting the outer shell to uniform product pressure. This full product pressure could only be developed for liquid slurry condition, but 5' head on dry product will conservatively be considered for design of both the inner and outer shell. Vessel is supported at a stiffened rectangular compression bar (base plate) at top of vault walls, and vessel is anchored to tops of these walls.

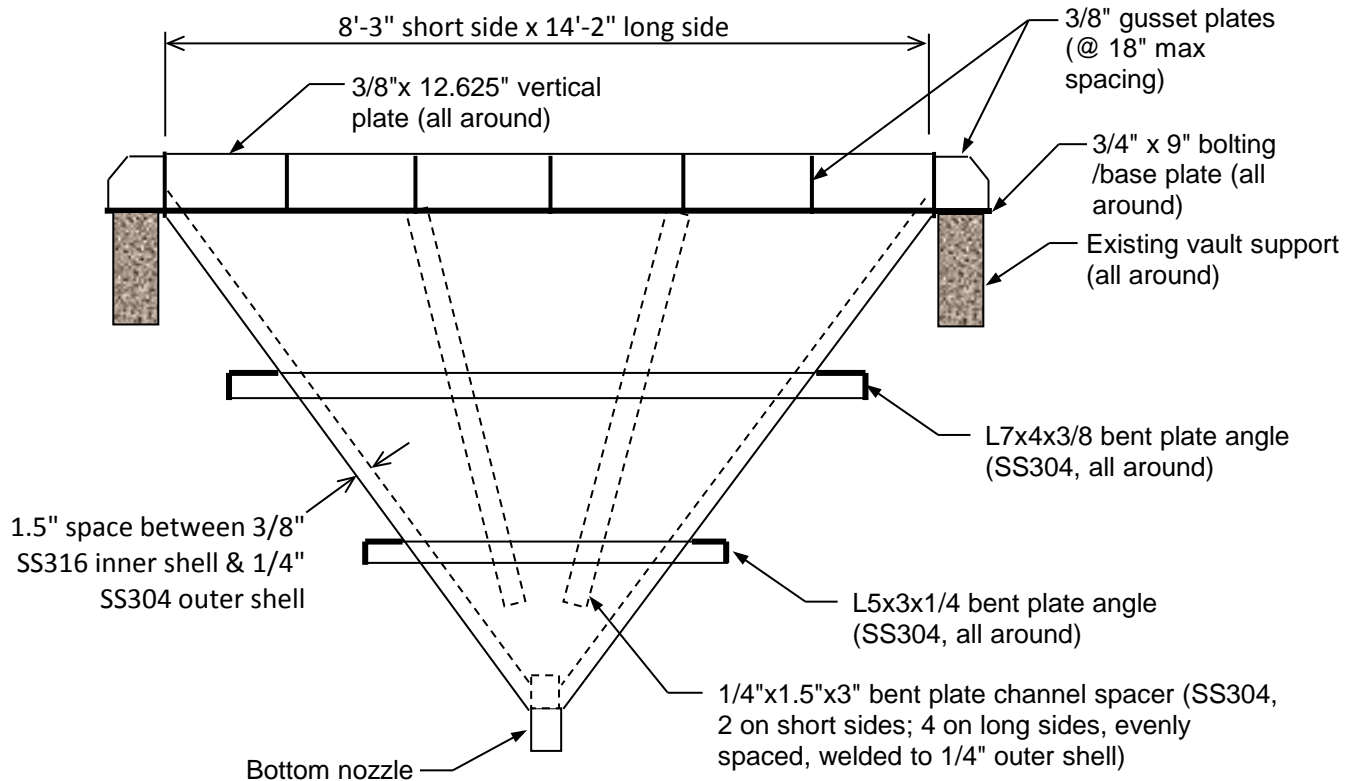
Vessel is replacing an similar existing hopper at same location. Vessel is supported on (3) walls of a concrete vault, and by an HSS8x8 along one (short) side. Existing anchor bolts are corroded and will be cut off and not reused. New epoxy anchors will be installed in existing concrete walls and welded to existing HSS tube. Check of existing concrete vault is beyond the scope of these calcs, but it should be adequate as hopper is being replaced in kind. For lateral load calculations, it is assumed that tank is a pendulum-type structure rigidly supported at anchor plates. For seismic OTM calculations, product head above the anchor bolt circle is conservatively ignored.

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Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
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Design Criteria & Sketch

Product Stored: Spent Activated Carbon (Design for Both Liquid Slurry & Dry Granular Material)
Specific Gravity: 1.50
Max Temperature: 150° F
Min Design Metal Temp: -20° F
Design Pressure: 0 psig (atmospheric)
Corrosion Allowance: 0 in
Design Codes: 1) API 650 11th Ed.
2) IBC 2012 for Wind & Seismic
Seismic Design: $S_s = 0.23g$, $S_1 = 0.15g$, $F_a = 1.60$, $F_v = 2.40$, $I_e = 1.5$, Site Class D
Seismic Design Category B
Wind Design: Not Required



Weights: Empty Vessel = W_{empty} = 7.5 k
Product in tank (full to grating level) = 25.3 k
Tank + operating product = W_{full1} = 32.8 k
5' head of dry product above top of grating = 54.7 k
Tank + operating product + head = W_{full2} = 87.5 k

IBC 2012 Seismic Design Loads

IBC 2012 Seismic Design Loads: (ref ASCE 7-10 Sections 13 & 15)

Governing Seismic Design Acceleration:

Horizontal:	$A_i = (0.4a_p S_{DS} I_p) [1 + 2(z/h)] / R_p =$	0.059 g	(Eq 13.3-1)
	or, $A_i = 0.3 S_{DS} I_e =$	0.110 g	GOVERNS (Eq 15.4-5)
	Where: $S_{DS} = (2/3) F_a S_s =$	0.245	
	$F_a =$	1.600	
	$S_s =$	0.230	
	$a_p =$	1.0	
	$R_p =$	2.5 (per ASCE 7-10, Table 13.6-1)	
	$I_e = I_p =$	1.50	
Vertical:	$A_v = 0.2 S_{DS} I_p =$	0.074 g	

Base Shear: (ref ASCE 7-10 Eq. 12.8-1)

Vessel full:	$V_{s-full} = A_i W_{full2} =$	9.66 k	GOVERNS
	Where: Design acceleration $= A_i = C_s =$	0.110 g	
	$W_{full2} =$	87.50 k	

Vessel empty:	$V_{s-empty} = A_i W_{empty} =$	0.83 k	
	$W_{empty} =$	7.50 k	

Overtuning Moments (at anchor plate level):

Vessel full:	$M_{s-full} = (V_{s-full})(CG_{full}) =$	16.91 ft-k	GOVERNS
	Where: $CG_{full} =$	1.75 ft (below top of vault / anchor plate)	
Vessel empty:	$M_{s-empty} = (V_{s-empty})(CG_{empty}) =$	1.45 ft-k	
	Where: $CG_{empty} =$	1.75 ft	

Resisting Moments (at anchor plate level, conserv. ignore product head above grating):

Vessel full:	$M_{resist} = (0.6)(W_{full1})(8.25/2) =$	81.18 ft-k	
Vessel empty:	$M_{resist} = (0.6)(W_{empty})(8.25/2) =$	18.56 ft-k	

(Since OTM < resisting moment, hopper is stable for seismic overturning)

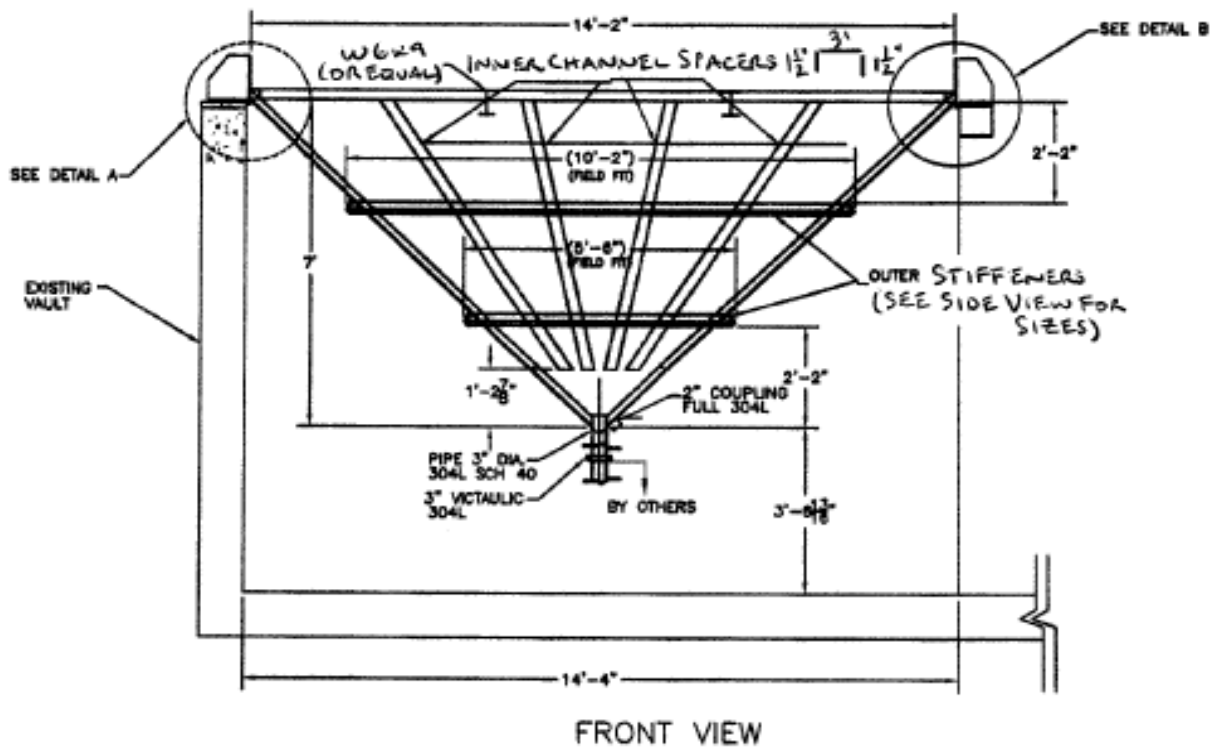
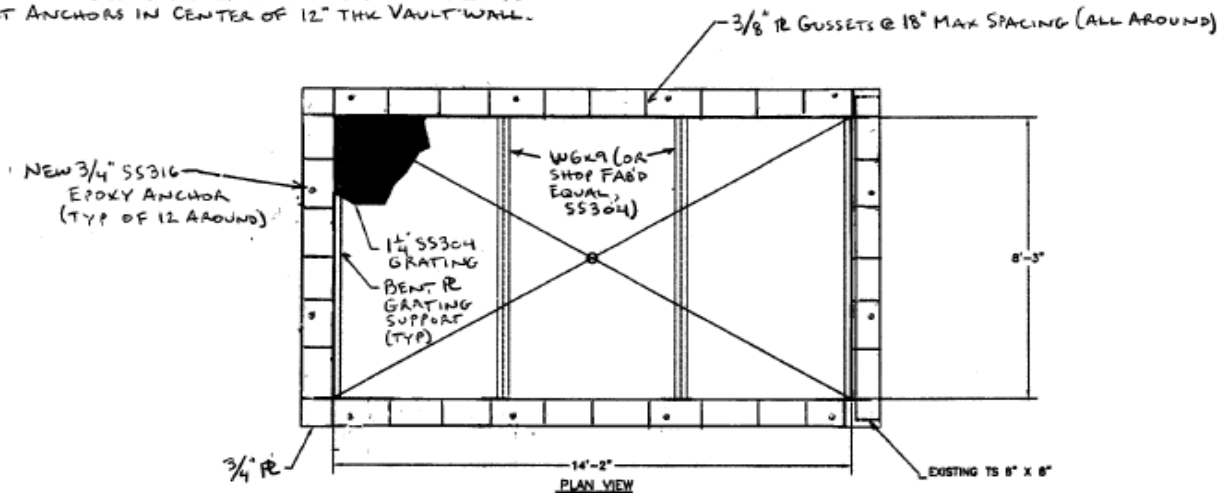
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Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
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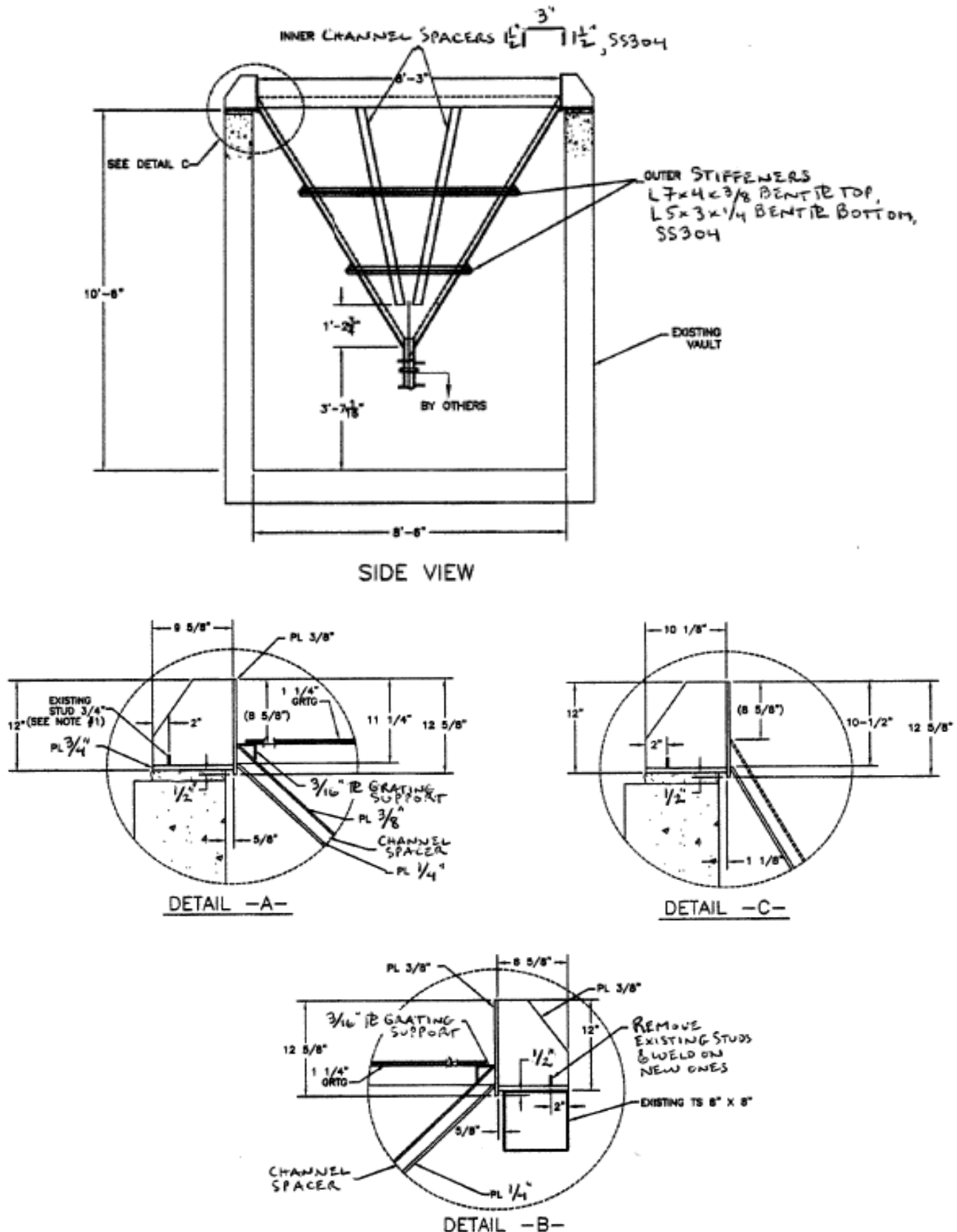
Hopper Details

NOTES:

- 1) CUT EXISTING CORRODED STUDS FLUSH W/ TOP OF VAULT WALLS.
- 2) FIELD DALL & INSTALL (12) NEW HILTI EPOXY ANCHORS IN LOCATIONS SHOWN AFTER HOPPER IS SET IN PLACE. SET ANCHORS IN CENTER OF 12" THK VAULT WALL.



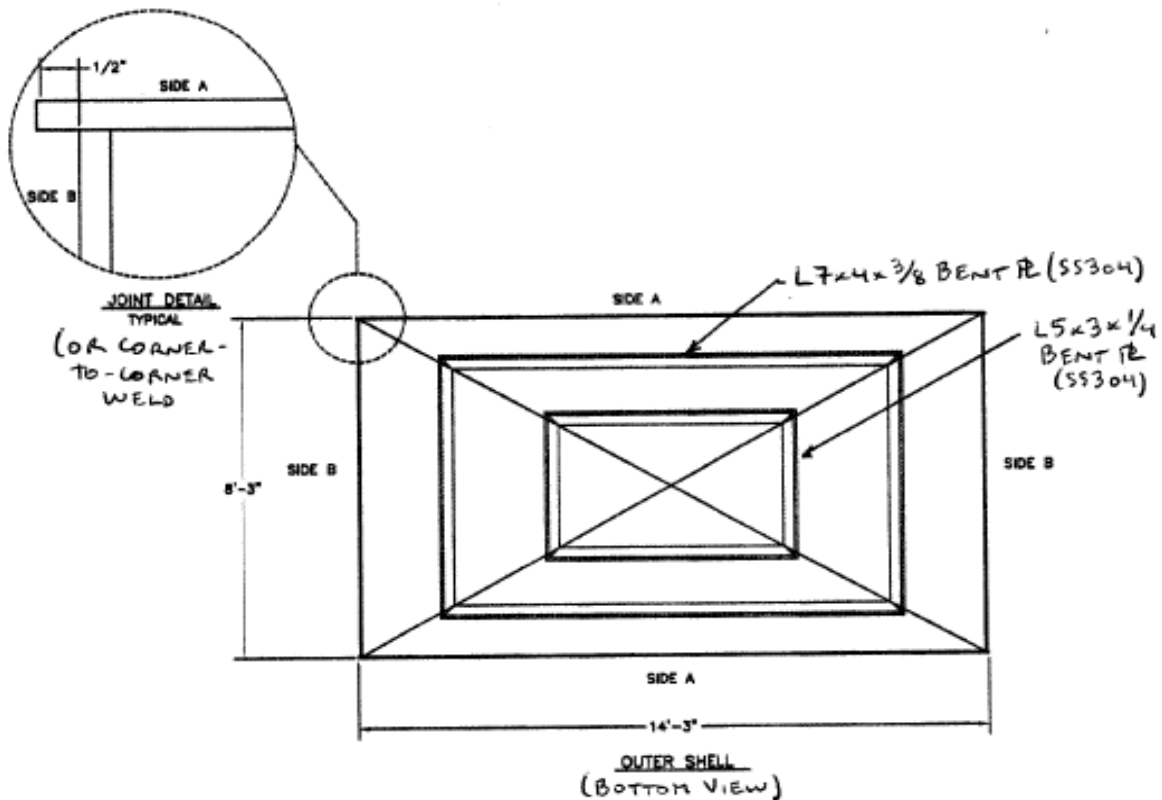
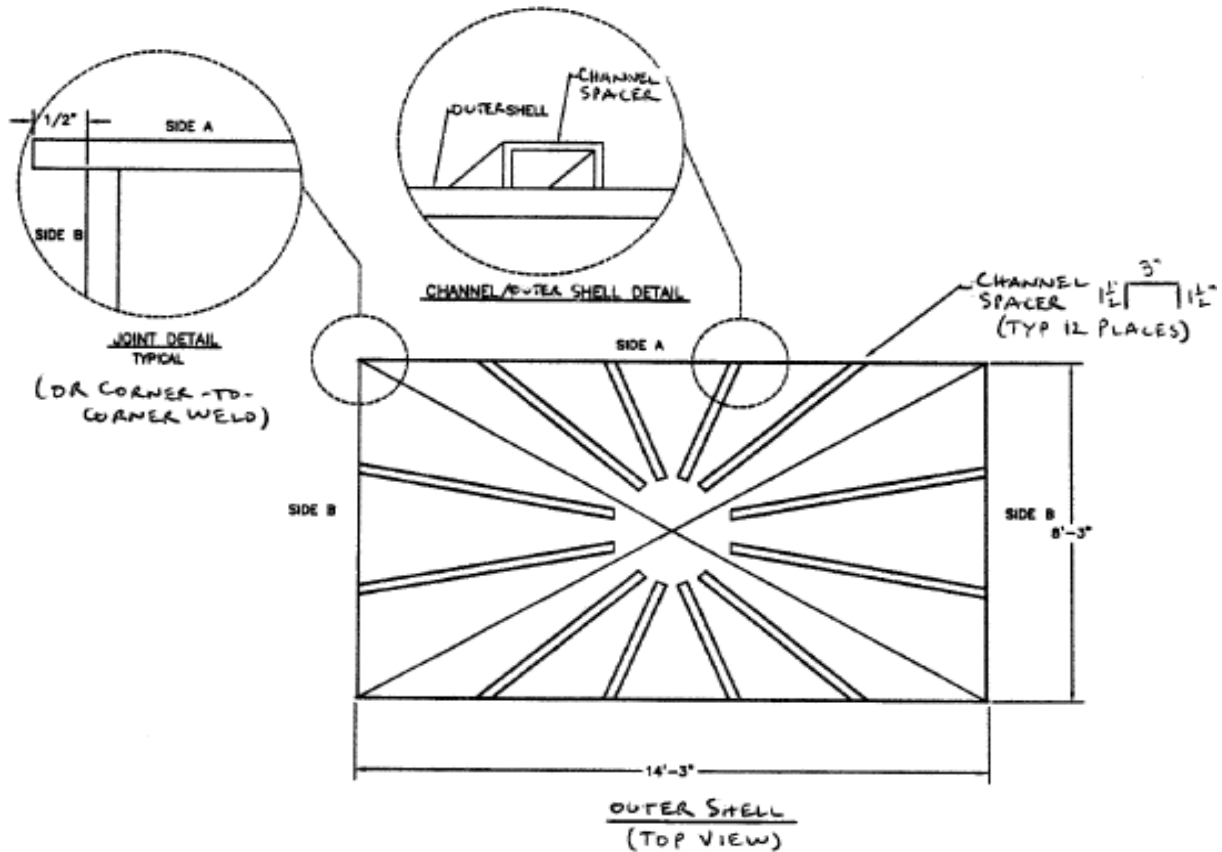
Hopper Details, cont.



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Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
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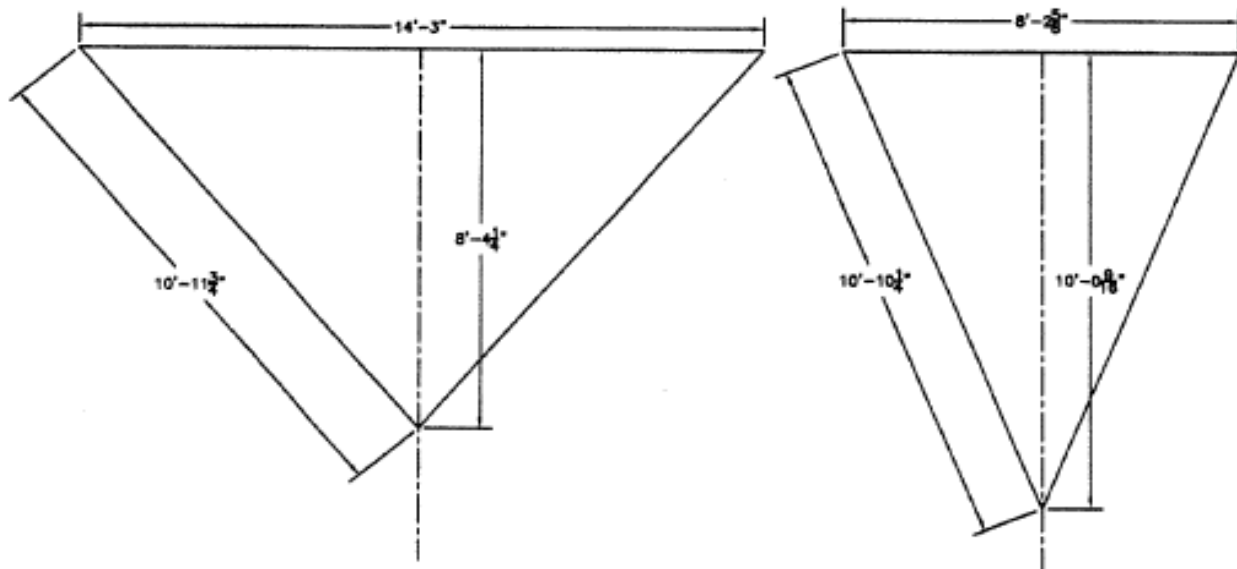
Hopper Details, cont.



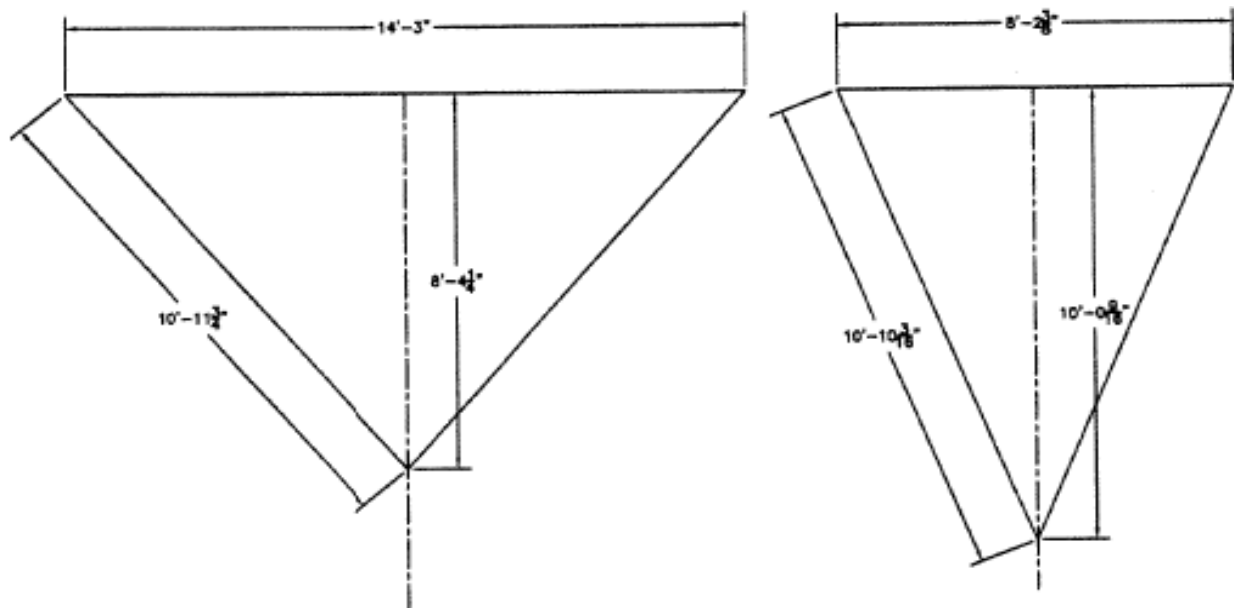
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Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
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Hopper Details, cont.



INNER SHELL
SIDE A
3/8" PLT 316SS (2 NEEDED)
SIDE B
3/8" PLT 316SS (2 NEEDED)



OUTER SHELL
SIDE A
1/4" PLT 304SS (2 NEEDED)
SIDE B
1/4" PLT 304SS (2 NEEDED)

Design Hopper Components

Spacing of C3x1.5x1/4 Spacers Between Inner & Outer Walls

- Spacers are welded to 1/4" outer shell with min weld shown below
- Support spacing for 1/4" outer wall governs over 3/8" thick inner hopper wall
- Consider granular material with 5' head as governing condition for these checks

Check plate midway down hopper wall:

Max allowable stiffener spacing:

$$L_s = (54000t^2/p)^{1/2} = 30.3 \text{ in}$$

Where: $t = 0.25 \text{ in}$

$p = 3.68 \text{ psi}$

Max actual stiffener spacing = 17 in

< Allowable, OK

Check midway between upper horz stiffener and grating:

Max allowable stiffener spacing:

$$L_s = (54000t^2/p)^{1/2} = 35.0 \text{ in}$$

Where: $t = 0.25 \text{ in}$

$p = 2.76 \text{ psi}$

Max actual stiffener spacing = 29.3 in

< Allowable, OK

Check C3x1.5x1/4 Stiffeners/Spacers Between Inner & Outer Walls

Short side of hopper

Check stiffener midway down hopper wall:

$$f_b = M/S = 9845 \text{ psi}$$

Where: $M = wL^2/8 = 12110 \text{ in-lbs}$

$w = 60.7 \text{ pli}$

$L = 40.0 \text{ in}$

$S = 1.23 \text{ in}^3$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

Check midway between upper horz stiffener and grating:

$$f_b = M/S = 12978 \text{ psi}$$

Where: $M = wL^2/8 = 15963 \text{ in-lbs}$

$w = 80.0 \text{ pli}$

$L = 40.0 \text{ in}$

$S = 1.23 \text{ in}^3$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

Long side of hopper

Check stiffener midway down hopper wall:

$$f_b = M/S = 7053 \text{ psi}$$

Where: $M = wL^2/8 = 8675 \text{ in-lbs}$

$w = 62.5 \text{ pli}$

$L = 33.3 \text{ in}$

$S = 1.23 \text{ in}^3$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

Check midway between upper horz stiffener and grating:

$$f_b = M/S = 9088 \text{ psi}$$

Where: $M = wL^2/8 = 11178 \text{ in-lbs}$

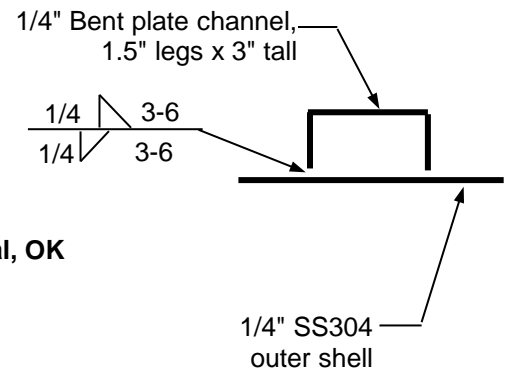
$w = 80.5 \text{ pli}$

$L = 33.3 \text{ in}$

$S = 1.23 \text{ in}^3$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK



Channel Spacer Details

Check Hopper Components, cont.

Angle Stiffeners on Outside of Exterior Shell

Upper stiffener (governing condition is long side)

$$f_b = M/S = 15587 \text{ psi}$$

$$\text{Where: } M = wL^2/8 = 199508 \text{ in-lbs}$$

$$w = 107.2 \text{ pli}$$

$$L = 122.0 \text{ in}$$

$$\text{Try L7x4x3/8 welded to 1/4" shell, } S = 12.8 \text{ in}^3$$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

Lower stiffener (governing condition is long side)

$$f_b = M/S = 15135 \text{ psi}$$

$$\text{Where: } M = wL^2/8 = 75071 \text{ in-lbs}$$

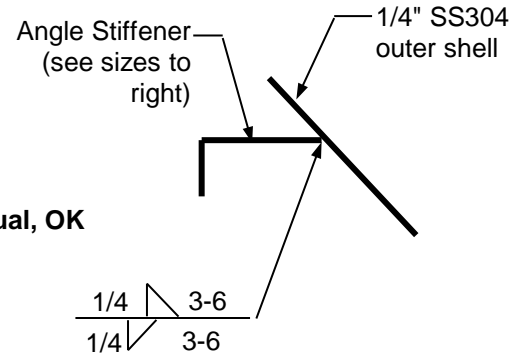
$$w = 137.9 \text{ pli}$$

$$L = 66.0 \text{ in}$$

$$\text{Try L5x3x1/4 welded to 1/4" shell, } S = 4.96 \text{ in}^3$$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK



Exterior Stiffener Details

Top Compression Bar

Short side of hopper: $f_b = M/S = 8421 \text{ psi}$

$$\text{Where: } M = wL^2/8 = 117563 \text{ in-lbs}$$

$$w = 96.0 \text{ pli}$$

$$L = 99.0 \text{ in}$$

$$\text{Try FB 3/4"x 9" welded to 3/8" x 12.625" vert plate, } S = 13.96 \text{ in}^3$$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

Long side of hopper: $f_b = M/S = 14464 \text{ psi}$

$$\text{Where: } M = wL^2/8 = 201923 \text{ in-lbs}$$

$$w = 55.9 \text{ pli}$$

$$L = 170.0 \text{ in}$$

$$\text{Try FB 3/4"x 9" welded to 3/8" x 12.625" vert plate, } S = 13.96 \text{ in}^3$$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

3/8" x 12.625" Top Vertical Perimeter Plate

Max spacing of gussets for 5' of head pushing outward:

Max allowable gusset spacing:

$$L_s = (54000t^2/p)^{1/2} = 48.3 \text{ in}$$

$$\text{Where: } t = 0.375 \text{ in}$$

$$p = 3.25 \text{ psi}$$

$$\text{Max actual stiffener spacing} = 18 \text{ in (max)} < \text{Allowable, OK}$$

Check 18" spacing of gussets for forces due to hopper inner wall pulling inward:

$$f_b = M/S = 13134 \text{ psi}$$

$$\text{Where: } M = wL^2/8 = 3886 \text{ in-lbs}$$

$$w = 96.0 \text{ pli}$$

$$L = 18.0 \text{ in}$$

$$3/8" \times 12.625" \text{ tall plate, } S = 0.30 \text{ in}^3$$

$$F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi}$$

> Actual, OK

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Hopper H1 (270 cu ft Capacity)
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Design of Vessel & Supports
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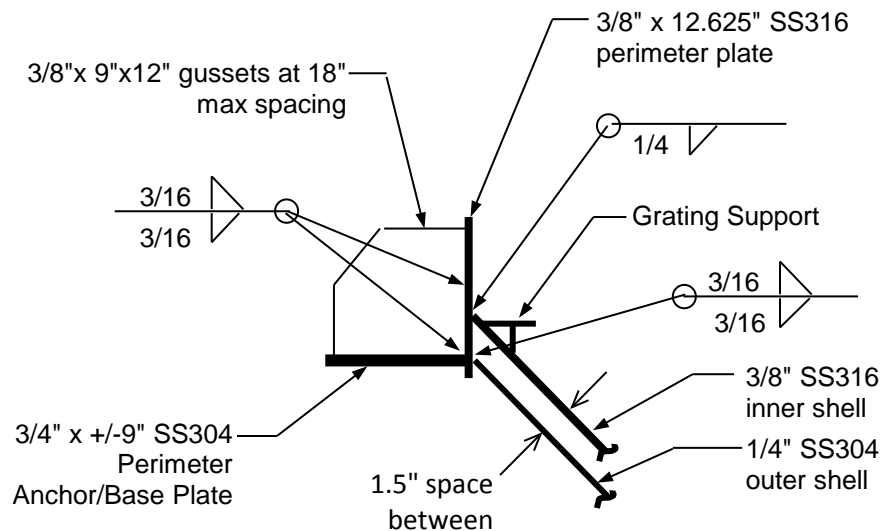
Check Hopper Components, cont.

Grating

Max span of bearing bars = 4.72 ft
Use 1 1/4" x 3/16" Galvanized Stainless Steel Bar Grating (19-W-4)
→ Allowable uniform load = 325 psf > 100 psf √ OK
(see attached grating data sheet)

Grating Support Beam

$f_b = M/S = 10408 \text{ psi}$
Where: $M = wL^2/8 = 57867 \text{ in-lbs}$
 $w = 47.2 \text{ pli}$
 $L = 99.0 \text{ in}$
Try W6x9 (or shop fab'd equal), $S = 5.56 \text{ in}^3$
 $F_b = (0.7)(22,500 \text{ psi}) = 15750 \text{ psi} > \text{Actual, OK}$



Section thru Top Edge of Hopper

Hopper Grating

Per chart below, 1 1/4 x 3/16 W-19-4 stainless steel grating is OK for up to 325 psf > 100 psf. ✓ OK

Stainless Steel Grating Load Table

19-4 / 19-2 LOAD TABLE																																																																																																																																															
BEARING BAR SIZE		UNSUPPORTED SPAN													WEIGHT PER SQ. FT. (LBS.)																																																																																																																																
		2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"	9'-0"	19-4	19-2	15-4	15-2	11-4	11-2	7-4	7-2																																																																																																																									
3/4 X 1/8	U	.395	.253	.175	.129	.99	.78	LOADS AND DEFLECTIONS ARE THEORETICAL VALUES BASED ON 20,000 PSI UNIT STRESS. FOR PEDESTRIAN COMFORT DEFLECTIONS IN EXCESS OF 1/4" ARE NOT RECOMMENDED.																																																																																																																																							
	D	.114	.179	.257	.350	.457	.579																																																																																																																																								
	C	.395	.316	.263	.226	.197	.175																																																																																																																																								
	D	.091	.143	.206	.280	.366	.463																																																																																																																																								
3/4 X 3/16	U	.592	.379	.263	.193	.148	.117																	U = SAFE UNIFORM LOAD, LBS. PER SQ. FT. C = SAFE CONCENTRATED MID- SPAN LOAD, LBS. PER FT. OF GRATING WIDTH D = DEFLECTION IN INCHES																																																																																																																							
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	C	.592	.474	.395	.338	.296	.263																																																																																																																																								
	D	.091	.143	.206	.280	.366	.463																																																																																																																																								
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	C	.702	.561	.468	.401	.351	.312																																.281	.255	.234																																																																																																						
	D	.069	.107	.154	.210	.274	.347																																.429	.519	.617																																																																																																						
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	C	.2368	.1895	.1579	.1353	.1184	.1053																																.947	.861	.789																									.729	.677																					.592	.526																																																						
	D	.046	.071	.103	.140	.183	.231																																.286	.346	.411																									.483	.560																					.731	.926																																																						
1-3/4 X 3/16	U	.3224	.2063	.1433	.1053	.806	.637																																.516	.426	.358																									.305	.263																					.201	.159																			U = SAFE UNIFORM LOAD, LBS. PER SQ. FT. C = SAFE CONCENTRATED MID- SPAN LOAD, LBS. PER FT. OF GRATING WIDTH D = DEFLECTION IN INCHES																																			
	D	.049	.077	.110	.150	.196	.248																																.306	.370	.441																									.517	.600																					.784	.992																																																						
	C	.3224	.2579	.2149	.1842	.1612	.1433																																.1289	.1172	.1075																									.992	.921																					.806	.716																																																						
	D	.039	.061	.088	.120	.157	.198																																.245	.296	.353																									.414	.480																					.627	.793																																																						
2 X 3/16	U	.4211	.2695	.1871	.1375	.1053	.832																																.674	.557	.460																									.399	.344																					.263	.208																												U = SAFE UNIFORM LOAD, LBS. PER SQ. FT. C = SAFE CONCENTRATED MID- SPAN LOAD, LBS. PER FT. OF GRATING WIDTH D = DEFLECTION IN INCHES																										
	D	.043	.067	.096	.131	.171	.217																																.268	.324	.386																									.453	.525																					.686	.868																																																						
	C	.4211	.3368	.2807	.2406	.2105	.1871																																.1684	.1531	.1404																									.1296	.1203																					.1053	.936																																																						
	D	.034	.054	.077	.105	.137	.174																																.214	.259	.309																									.362	.420																					.549	.694																																																						
2-1/4 X 3/16	U	.5329	.3411	.2368	.1740	.1332	.1053																																.853	.705	.592																									.505	.435																					.333	.263																																					U = SAFE UNIFORM LOAD, LBS. PER SQ. FT. C = SAFE CONCENTRATED MID- SPAN LOAD, LBS. PER FT. OF GRATING WIDTH D = DEFLECTION IN INCHES																	
	D	.038	.060	.086	.117	.152	.193																																.238	.288	.343																									.402	.467																					.610	.771																																																						
	C	.5329	.4263	.3553	.3045	.2664	.2368																																.2132	.1938	.1776																									.1640	.1523																					.1332	.1184																																																						
	D	.030	.048	.069	.093	.122	.154																																.190	.230	.274																									.322	.373																					.488	.617																																																						
2-1/2 X 3/16	U	.6579	.4211	.2924	.2148	.1645	.1300																																.1053	.870	.731																									.623	.537																					.411	.325																																														U = SAFE UNIFORM LOAD, LBS. PER SQ. FT. C = SAFE CONCENTRATED MID- SPAN LOAD, LBS. PER FT. OF GRATING WIDTH D = DEFLECTION IN INCHES								
	D	.034	.054	.077	.105	.137	.174																																.214	.259	.309																									.362	.420																					.549	.694																																																						
	C	.6579	.5263	.4386	.3759	.3289	.2924																																.2632	.2392	.2193																									.2024	.1880																					.1645	.1462																																																						
	D	.027	.043	.062	.084	.110	.139																																.171	.207	.247																									.290	.336																					.439	.555																																																						

NOTE: WHEN GRATINGS WITH SERRATED BEARING BARS ARE SELECTED, THE DEPTH OF GRATING REQUIRED TO SERVICE A SPECIFIED LOAD WILL BE 1/4" GREATER THAN THAT SHOWN IN THE TABLES ABOVE.

CONVERSION TABLE

The loads shown above are for type 19-4 and 19-2 gratings. To determine the load carrying capacity for alternative bar spacings, multiply the loads given by the following conversion factors (DEFLECTION REMAINS CONSTANT): **FOR TYPES 15-4 AND 15-2: 1.26** **FOR TYPES 11-4 AND 11-2: 1.72** **FOR TYPES 7-4 AND 7-2: 2.71**

SELECTION GUIDE: 19-4 PLAIN SURFACE GRATING

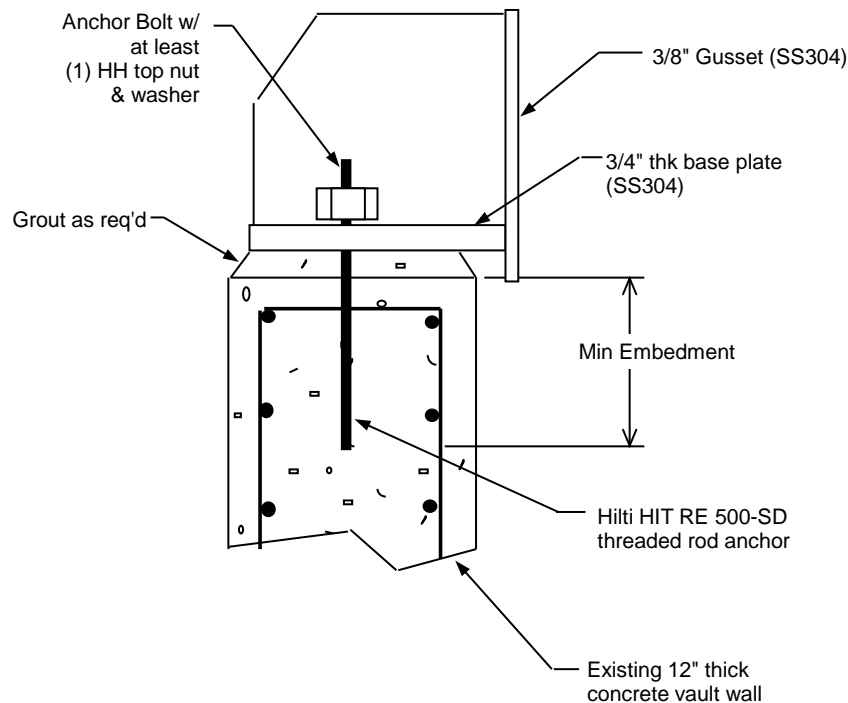
For deflection of not more than 1/4" when subjected to the severest of the following: (1) the uniform loads below; (2) under concentrated mid-span loads of 300 lbs. up to 6'-0" span; or (3) 400 lbs. for spans 6'-0" and over.

SAFE UNIFORM LOAD LBS./SQ. FT.	2'-0"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"	9'-0"
50	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16
75	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16
100	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2-1/4 x 3/16	2-1/2 x 3/16
125	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16	-
150	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2 x 3/16	2-1/2 x 3/16	-
200	1 x 1/8	1 x 1/8	1 x 1/8	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16	-	-
300	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2 x 3/16	2-1/4 x 3/16	2-1/2 x 3/16	-	-

For: Evoqua Water Technologies
Parker, Arizona
By: John F. Bradley, S.E.
October 3, 2014

Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
Sheet 14

Anchorage Summary - Hilti Epoxy Anchor Option



Anchor Bolt Summary

Use (12) - 0.75 inch diameter threaded rod Anchor Bolts Around Base Plate

Material = ASTM F593 CW2 (316) (threaded rod)

(Recommended min) Projection above concrete = 3 in + grout thickness (if this vessel is grouted)

Min Embedment = 6.0 in

Min Edge Distance = 6.0 in (all sides of all anchor bolts)

Min Concrete f'_c = 4000 psi

For: Evoqua Water Technologies
Parker, Arizona
By: John F. Bradley, S.E.
October 3, 2014

Hopper H1 (270 cu ft Capacity)
Location: Parker, Arizona
Design of Vessel & Supports
Sheet 15

Tank Anchorage (Hilti Epoxy Anchors)

Check Anchor Bolts per IBC 2012 "Strength Design", ACI 318-11, Appendix D & Hilti ESR-2322.

Trial Input Data

Bolt diameter (d_o) =	0.750 in dia.
Bolt material =	ASTM F593 CW2 (316) (threaded rod)
Yield strength of bolt material =	45 ksi
Bolt embedment depth (h_{ef}) =	6 in
Minimum bolt edge distance (c_1) =	6 in
Cross-sectional area of bolt (A_d) =	0.44 in ²
Tensile stress area of bolt (A_{se}) =	0.334 in ²
Minimum root area of bolt (A_r) =	0.302 in ²
Minimum Concrete f_c' =	4000 psi
Seismic overturning moment (M_s) =	16.91 ft-k
Seismic Base Shear (V_s) =	9.66 k
Empty wt. of tank =	7.5 k
Full wt. product & tank (W_T) =	32.8 k

Seis. pullout for IBC strength level equations = $1.0E_{tension} - 0.6D$ =	0.01 k/bolt
Where: $E_{tension}$ =	0.50 k/bolt
D =	0.81 k/bolt

Seismic shear used in IBC strength level equations = $1.0E_{shear}$ = 1.21 k/bolt
(conservatively ignore resisting friction due to weight of tank & product)

Total strength level design pullout (N_u) =	0.01 k/bolt
Total strength level design shear (V_u) =	1.21 k/bolt

Per IBC 2012 Anchor Bolts are Acceptable If:

Anchor bolt tensile strength is greater than factored tension load: $\phi N_n > N_u$
and anchor bolt shear strength is greater than factored shear load: $\phi V_n > V_u$

And if interaction checks are satisfied (see loads below):

Case 1) Steel strength:	$N_u/\phi N_s + V_u/\phi V_s =$	0.118	< 1.2 -- OK
Case 2) Concrete breakout:	$N_u/\phi N_{cb} + V_u/\phi V_{cb} =$	0.284	< 1.2 -- OK

Therefore Anchors are OK per Interaction Checks

Tank Anchorage (Hilti Epoxy), cont.

Check anchor bolt tension:

- Check following cases:
- 1) Steel strength of anchor in tension: $\phi N_s > N_u$
 - 2) Concrete breakout strength of anchor in tension: $\phi N_{cb} > N_u$
 - 3) Pullout strength of anchor in tension: $\phi N_{pn} > N_u$
 - 4) Concrete side-face blowout strength of anchor in tension: $\phi N_{sb} > N_u$

Factored seismic uplift load per bolt (N_u) = **0.01 k** (see above)

Case (1): Steel strength of anchor in tension: $\phi N_s > N_u$

$$\phi N_s = \phi A_{se} f_{ut} = \mathbf{18.56 \text{ k}} > \mathbf{0.01 \text{ k}} \text{ -- OK}$$

Where: $\phi = 0.65$
 $f_{ut} = 85.5 \text{ ksi}$

ESR-1682 Test Results (for reference only): **12.39 k** > **0.01 k** -- OK

Case (2): Concrete breakout strength of anchor in tension: $\phi N_{cb} > N_u$

$$\phi N_{cb} = (\phi)(A_{Nc}/A_{Nco})(\psi_{ed,N})(\psi_{c,N})(\psi_{cp,N})(N_b) = \mathbf{9.99 \text{ k}} > \mathbf{0.01 \text{ k}} \text{ -- OK}$$

Where: $\phi = 0.65$
 $A_{Nc} = 225 \text{ in}^2$
 $A_{Nco} = 9h_{ef}^2 = 324 \text{ in}^2$
 $\psi_{ed,N} = 0.7 + (0.3c)/(1.5h_{ef}) = 1.0$
 $\psi_{c,N} = 1.4$
 $\psi_{cp,N} = 1.0$
 $N_b = k(f'_c)^{1/2}(h_{ef})^{1.5} = 15.8 \text{ k}$
 $k = 17$

Case (3): Pullout strength of anchor in tension (see Hilti ESR-2322,4.1.4):

$$\phi N_a = (\phi)(A_{Na}/A_{NaO})(\phi_{p,Na} N_{aO}) = \mathbf{14.38 \text{ k}} > \mathbf{0.01 \text{ k}} \text{ -- OK}$$

Where: $\phi = 0.65$
 $\phi_{p,Na} = 1.4$
 $A_{Na} = 245 \text{ in}^2$
 $A_{NaO} = 245 \text{ in}^2$
 $N_{aO} = \pi \tau_{kcr} d h_{ef} = 15.80 \text{ k}$

Case (4): Concrete side-face blowout strength of anchor in tension: $\phi N_{sb} > N_u$

$$\phi N_{sb} = \phi 160c(A_{brg})^{0.5}(f'_c)^{0.5} = \mathbf{N/A \text{ k}}$$

Equation does not apply since bolts are post-installed & not headed.
Since edge distance is 6 in, side blowout is not an issue
(ref. edge distance requirements in Hilti data sheets).

Therefore Anchors are OK for Tension Loads

Tank Anchorage (Hilti Epoxy), cont.

Check anchor bolt shear:

- Check following cases:
- 1) Steel strength of anchor in shear: $\phi V_s > V_u$
 - 2) Concrete breakout strength of anchor in shear: $\phi V_{cb} > V_u$
 - 3) Concrete pryout strength of anchor in shear: $\phi V_{cp} > V_u$

Factored seismic shear load per bolt (V_u) = **1.21 k** (see above)

Case (1): Steel strength of anchor in shear: $\phi V_s > V_u$

Check #1: $\phi V_s = \phi 0.6 A_{se} f_{ut} =$ **10.28 k** > **1.21 k -- OK**

Where: $\phi =$ 0.60

$f_{ut} =$ 85.5 ksi

Check #2: $\phi V_s =$ **10.24 k** > **1.21 k -- OK**

Where: $V_s =$ **17.06 k** (see Hilti ESR-2322, Table 7)

ESR-1682 Test Results (for reference only): **6.38 k** > **1.21 k -- OK**

Case (2): Concrete breakout strength of anchor in shear: $\phi V_{cb} > V_u$

$\phi V_{cb} = (\phi)(A_{Vc}/A_{Vco})(\phi_{edV}\phi_{cv}V_b) =$ **4.27 k** > **1.21 k -- OK**

Where: $\phi =$ 0.60

$A_V =$ 135 in² (based on min dim's)

$A_{Vo} =$ 162 in²

$\phi_{edV} =$ 1.0

$\phi_{ecV} =$ 1.0

$V_b = 7(\ell/d_o)^{0.2}(d_o)^{1/2}(f'_c)^{1/2}(c_1)^{1.5} =$ 8.5 k

$\ell =$ 6.0 in

Case 3) Concrete pryout strength of anchor in shear: $\phi V_{cp} > V_u$

Check #1: $\phi V_{cp} = (\phi k_{cp} N_{cb}) =$ **18.44 k** > **1.21 k -- OK**

Where: $\phi =$ 0.60

$k_{cp} =$ 2.0

$N_{cb} = \phi N_{cb}/\phi =$ 15.4

Check #2: $\phi V_{cp} = (\phi k_{cp} N_a) =$ **26.55 k** > **1.21 k -- OK**

$N_a = (A_{Na}/A_{Na0})(\phi_{pNa} N_{ao}) =$ 22.12 k

$N_{ao} = \tau_{kcr} \pi d_{hef} =$ 15.80 k

$\tau_{kcr} =$ 1.12

$\phi_{pNa} =$ 1.00

$A_{Na} =$ 245 in²

$A_{Na0} =$ 245 in²

Therefore Anchors are OK for Shear Loads